34. LNG

Maritime Transport for LNG, Power Generation, and Electric Transmission*

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LNG

- In Japan, all of the 50 nuclear units have been gradually shut down as a result of the accident at the Fukushima Daiichi plant.
- The use of fossil-fueled generation, especially natural gas has increased due to the influence.
  - In 2010, natural gas accounts 29% of total electricity generation, while in 2012, it increases to 48%.
- It becomes more important to select exporting countries for LNG in terms not only of geopolitics but also of economic efficiency.

Transmission

- In Japan there exist no power transmission grids, which can transmit electricity power multilaterally, as in the EU.
- If the power grid is installed in Japan and the neighboring countries or in East Asia, it would strengthen energy security of each country.
- When the economic efficiency is relatively important factor for the grids installation
  - It is necessary to evaluate economic efficiencies for two methods of energy transportation by means of comparing the cost of the maritime transportation for LNG with that of electricity transmission.
Previous works

- **Economic analysis for LNG transportation**
  - Maxwell and Zhu (2011, Energy Economics)
  - Messner and Babies (2012, Polinares working paper)

- **Messner and Babies (2012)**
  - compare a cost of LNG transport with that of natural gas via pipeline, and show a break-even point for two methods.
Research objectives

- We consider economic efficiencies for two policies of energy transport:
  - Electric transmission
  - Maritime transport for LNG

- We calculate the costs for power generation by means of LNG transport and electricity purchase via transmission.

- A break-even point of the economic efficiency for both policies is derived by comparing each cost.
Generation cost

Total discounted value of the cost:

\[
\int_{0}^{T} e^{-\rho t} \xi Q_c (C_f + C_{om}) \, dt + Q_c I = Q_c \left( \frac{\xi (C_f + C_{om})}{\rho} (1 - e^{-\rho T}) + I \right)
\]

- \( T \) : Life time for the plant (yr)
- \( \rho \) : Discount rate (%)
- \( Q_c \) : Generation capacity (kW)
- \( \xi \) : time coefficient (8760h/yr)
- \( C_f \) : fuel cost (yen/kWh)
- \( C_{om} \) : O&M cost (yen/kWh)
- \( I \) : Investment cost (yen/kW)
Conversion of prices

- CIF price to fuel cost for the generation (METI, 2013)

\[ C_f = \frac{Q_e}{Q_\ell \eta} (P_c + \tau_o) \]

- \( Q_e \): Unit conversion of heat amount (3.6 MJ/kWh)
- \( Q_\ell \): Heat value for LNG (MJ/t)
- \( \eta \): Thermal efficiency of gas-fired generation (%)
- \( P_c \): CIF price for LNG (yen/t)
- \( \tau_o \): Petroleum and coal tax (yen/t)
Sea lanes network

- We calculate the distance from exporting country to Japan by means of a commercial maritime data (Lloyd's List Intelligence) and a sea lanes network data.
  - Nodes: port, canal and way point
  - Links between the nodes

- Volume of the sea lane passage
Parameters

- Costs for natural gas plant in Japan (OECD/NEA, 2010)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>192,650 yen/kW</td>
</tr>
<tr>
<td>Fuel</td>
<td>7.50187 yen/kWh</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>0.57365 yen/kWh</td>
</tr>
</tbody>
</table>

- Generation capacity $Q_c$: 1,000 MW
- Life time for the plant $T$: 40 yr
- Discount rate $\rho$: 5%

- Heat value for LNG $Q_\ell$: 54,600 MJ/t (METI*, 2007)
- Thermal efficiency of gas-fired generation $\eta$: 43.41 % (METI, 2007)
- Petroleum and coal tax $T_O$: 1,340 yen/t (METI, 2007)
- Transmission cost (DC; 1,000MW): $634 \times 10^6$ yen/km (METI, 2012)

*METI: Minister of Economy, Trade and Industry in Japan*
Confirmation of parameters

- **Comparison between fuel cost and CIF price**
  - Average CIF price for LNG in 2007: 50,873 yen/t
  - Conversion to fuel cost:
    \[
    C_f = \frac{Q_e}{Q_{\text{ef}}} (P_e + \tau_o)
    \]
    --> 7.93047 yen/kWh
  - This fuel cost is similar to that in OECD/NEA (2010)

- “Russia proposes exporting power to Japan” (Nikkei, 31 May 2013)
  - Total project cost of 570 billion yen in this newspaper (Natural gas plants of 4,000 MW)
  - Calculation setting:
    - Krilyon Cape to Soya Cape: 42 km
    - Construction cost in Russia: 127,856 yen/kW (OECD/NEA, 2010)

\[
(127,856 \text{ yen/kW} \times 1,000 \text{ MW} + 634 \times 10^6 \text{ yen/km} \times 42 \text{ km}) \times 4 \text{ plants} = 618 \text{ billion yen}
\]
Threshold distance

We obtain a threshold distance for a case in which the generation cost for LNG in Japan is equal to that for natural gas in other country and transmission cost from the country.

\[ C^J = \frac{Q_c}{e^{-\lambda x}} \left( \frac{\xi (C_f^R + C_{om}^R)}{\rho} \left( 1 - e^{-\rho x} \right) + I^R + C_{t,x} \right) \]

- Generation costs for natural gas in Russia (OECD/NEA, 2010)
  - Fuel: 4.04551 yen/kWh
  - O&M: 0.78037 yen/kWh
  - Construction: 127,856 yen/kW

- Transmission loss
  - Assumption: loss of 3% at 1,000 km (exponentially)

Threshold distance: 712.987 km

--> When the distance is smaller than the threshold, the electricity purchase has economic merit
Price of natural gas in Russia: 32,636 yen/t (OECD, 2010)
The LNG price at exporting country that is obtained from this analysis is approximately the same one as that in OECD/NEA (2010).
Effect of distance on purchase cost

For the purchase price of 6.5 yen/kWh, the break-even point is 20,779 km.

Break-even point: if electricity is purchased from exporting country farther than distance of the break-even point, the electricity purchase has no economic merit.
Effect of distance on purchase cost

The threshold price of electricity purchase is 6.89 yen/kWh. --> If the purchase price is more than 6.89 yen/kWh, the electricity purchase has no economic merit.
Summary

- We analyze the cost of power generation for natural gas taking into account the CIF price for LNG which is dependent on the distance from each exporting country.

- The natural gas price is about 30,000 yen/t, which is approximately the same one as that in OECD/NEA (2010).

- We show the break-even point of electricity costs for natural gas for LNG transport and electricity purchase from exporting country.
Future works

- Our analysis assumes an agreement system of electricity purchase.
  --> It is also necessary to consider other different systems such as cost sharing between importing and exporting countries.

- The analysis could be extended to allow for comparison of different agreement systems.
  - This would provide useful implications for energy policy.